High Frequency PIN-Diode Switches for Radiometer Applications

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Outline

1. Introduction
2. Description of Work
3. Design Topology
4. Switch Designs
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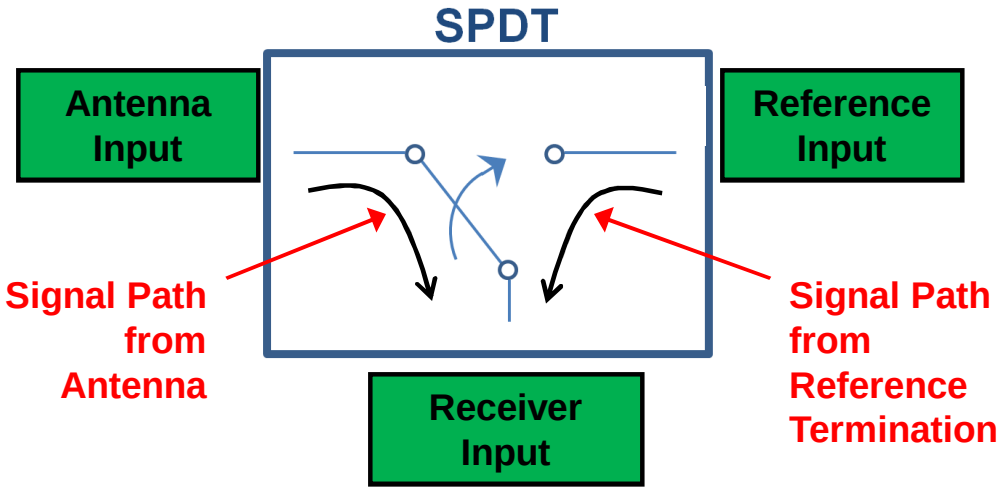
Introduction

- Dicke switched radiometers allow for correction of gain and noise figure fluctuations in components of receiver chain
- Accomplished using a single-pole double-throw (SPDT) RF MMIC switch
- Switches the input of the receiver between the signal from the antenna and a signal from a matched load internal to the radiometer



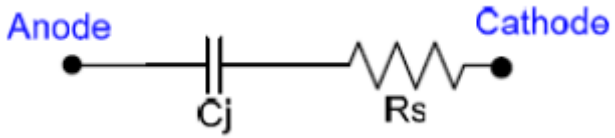
Description of Work

- Microwave switches were designed to cover three frequency ranges of 80-105 GHz, 90-135 GHz, and 160-190 GHz
- Monolithic microwave integrated circuits (MMIC) were realized in microstrip and coplanar waveguide technology
- Fabricated using Northrop Grumman's 75-μm thick InP MMIC PIN diode process
- PIN diodes used because of low insertion loss and fast switching speeds
- Variations of each SPDT design with PIN diode sizes ranging from 3 to 8 μm were fabricated
- To date, 80-105 GHz and 90-135 GHz switches have been tested; 160-190 GHz switches have not yet been tested

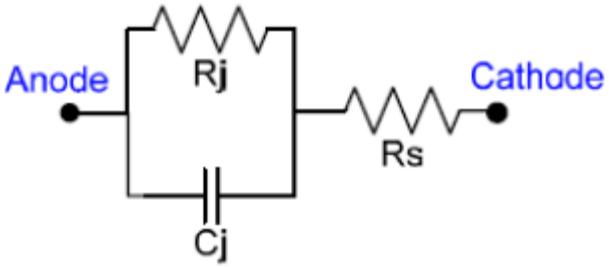
Design Topology

PIN diodes are used as switching elements

- Provide high impedance when reverse-biased because of relatively small junction capacitance of diode
- Provide low impedance path when forward-biased because of decreased junction resistance



Reverse Biased Small-Signal Model

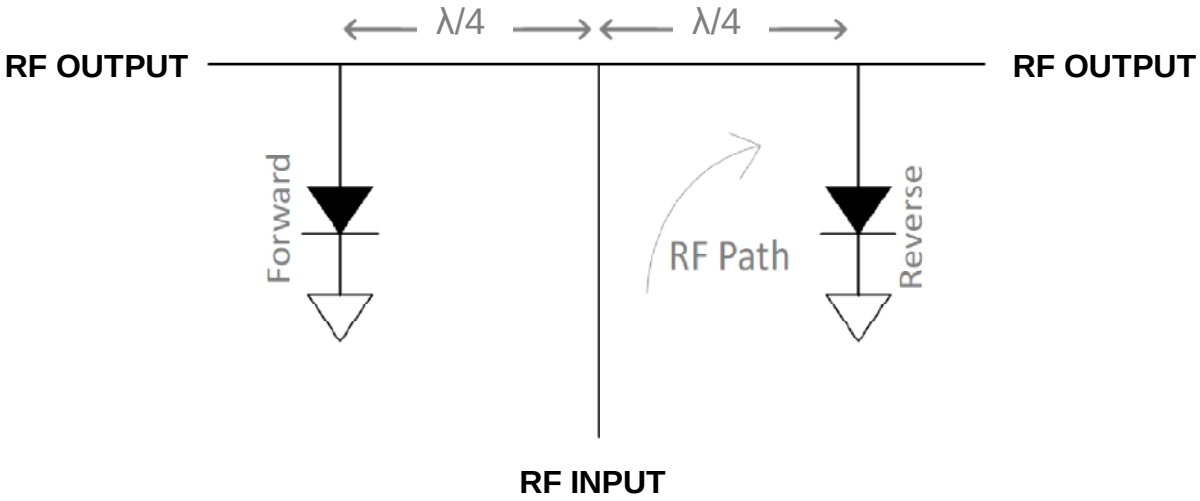


Forward Bias Small-Signal Model

Design Topology

Shunt PIN-diode SPDT Switch Implementation

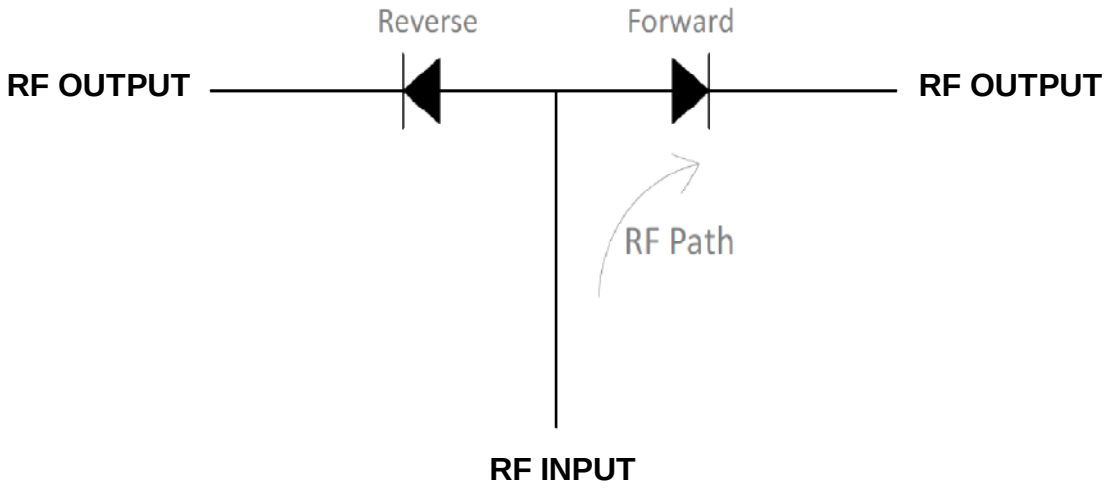
- Forward-biased diode provides RF short to ground (OFF state)
- Reverse-biased diode provides high impedance to ground and does not affect RF signal (ON state)



Design Topology

Series PIN-diode SPDT Switch Implementation

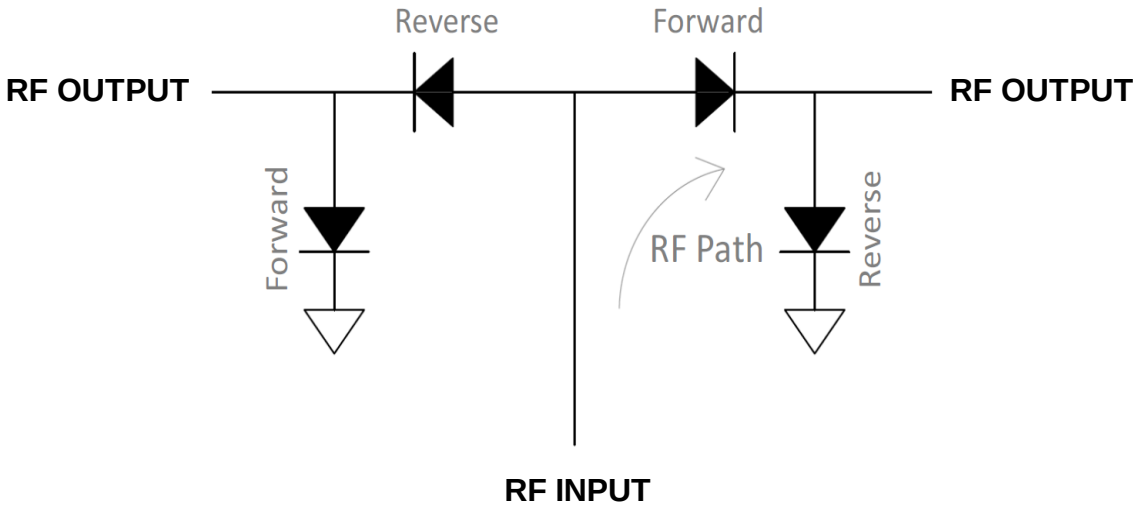
- Reverse-biased diode provides high impedance RF path (OFF state)
- Forward-biased diode provides low impedance RF path (ON state)



Design Topology

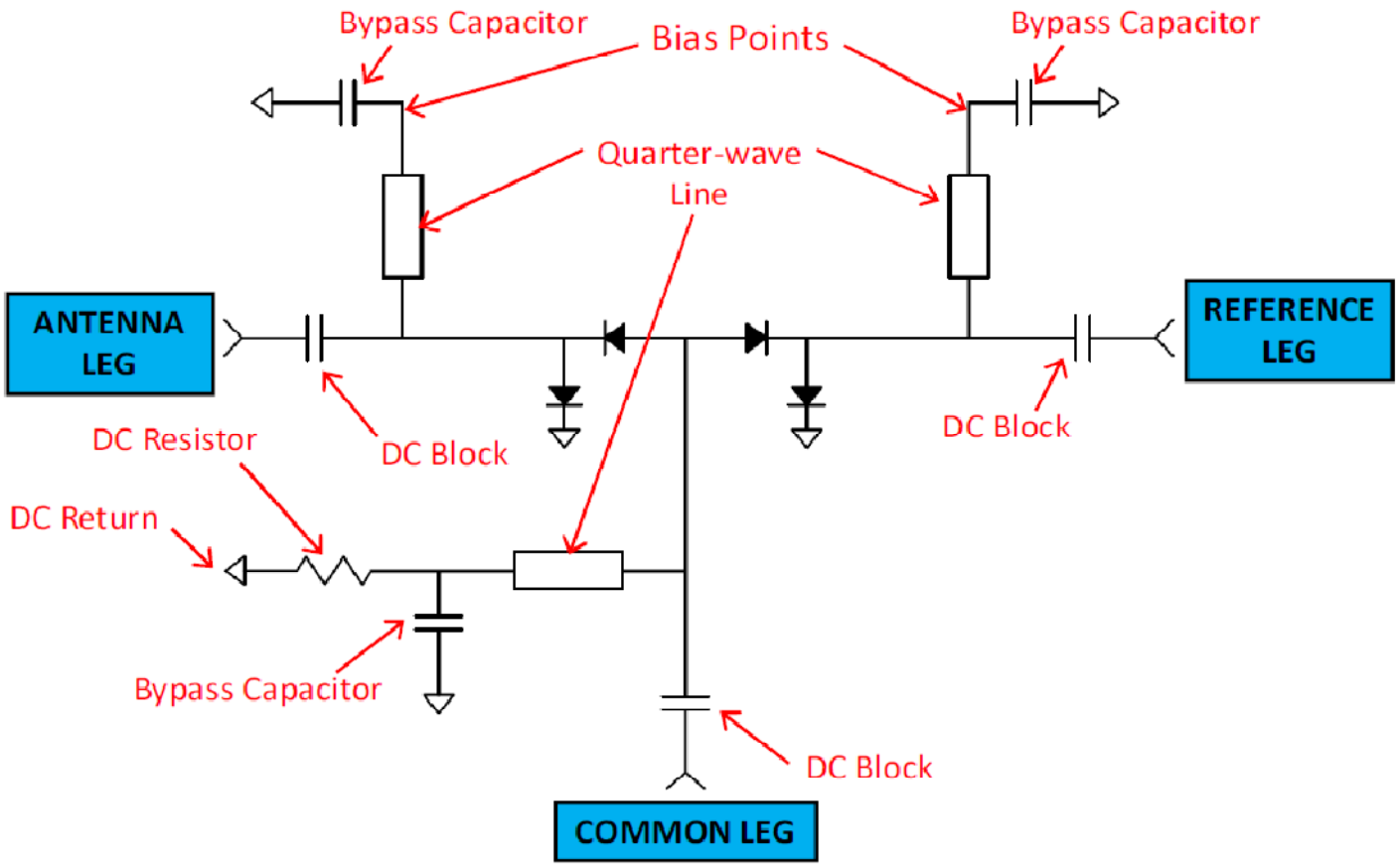
Series-Shunt PIN-diode SPDT Switch Implementation

- Implements both series and shunt diode SPDT configurations together to maximize isolation
- Eliminates the need for quarter-wave transformer (reduces size)
- This configuration was used for SPDT switch designs being presented



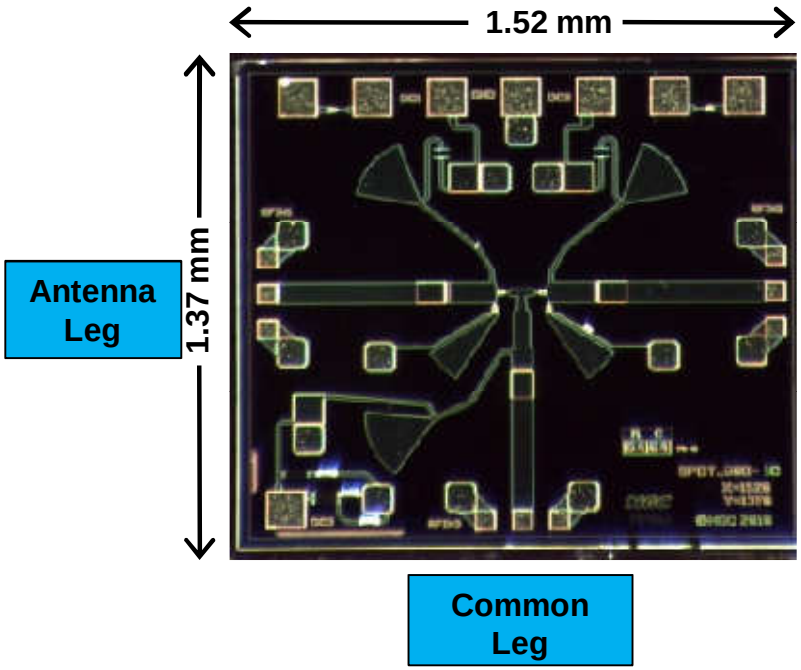
Design Topology

SPDT Switch Circuit Schematic



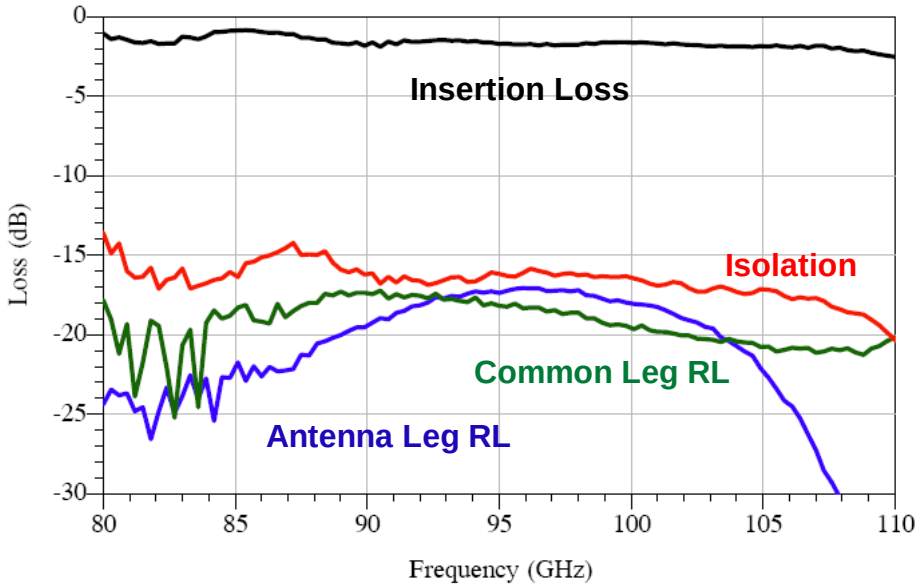
80-105 GHz MMIC Switch

Symmetric Design



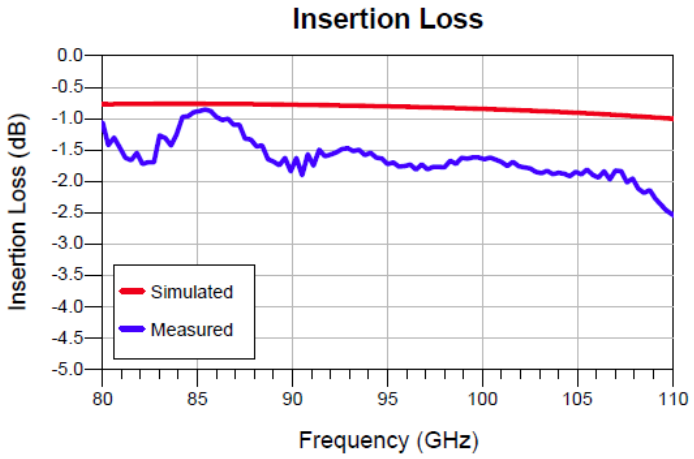
- Microstrip design
- SiN 2-layer MIM capacitors for bypass and DC blocking capacitors
- NiCr thin-film process for resistors
- Radial stubs used to provide well-defined virtual RF shorts

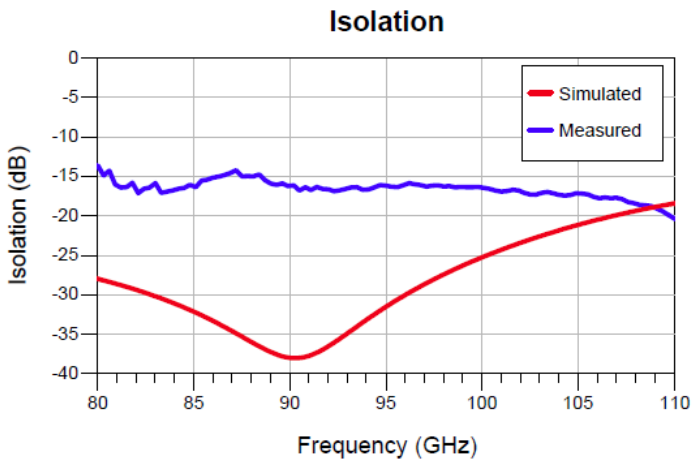
Measured Performance

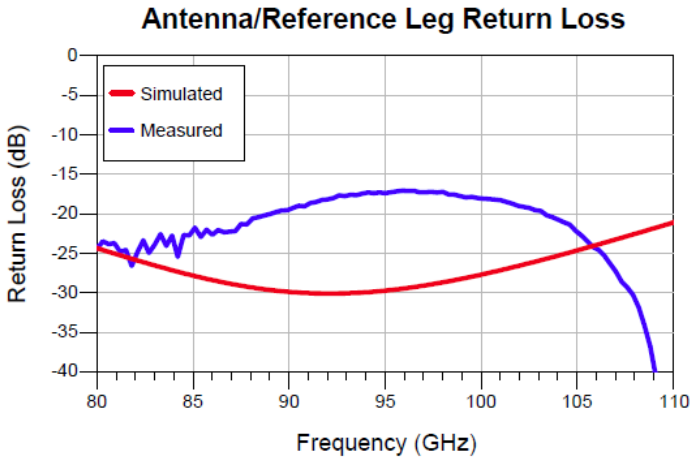


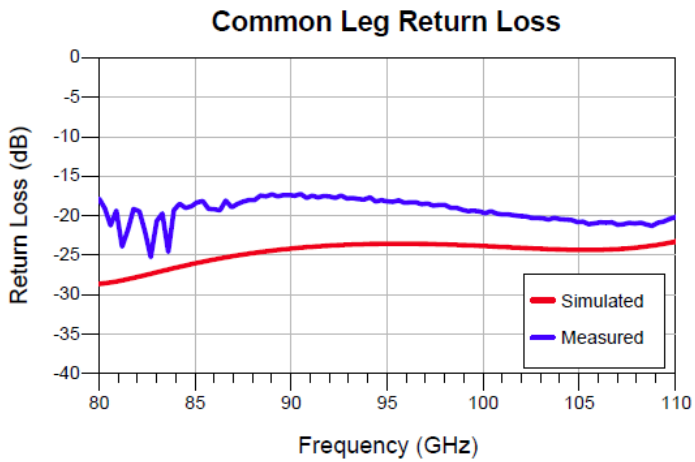
80-105 GHz MMIC Switch

Measured Results vs. Simulated Results





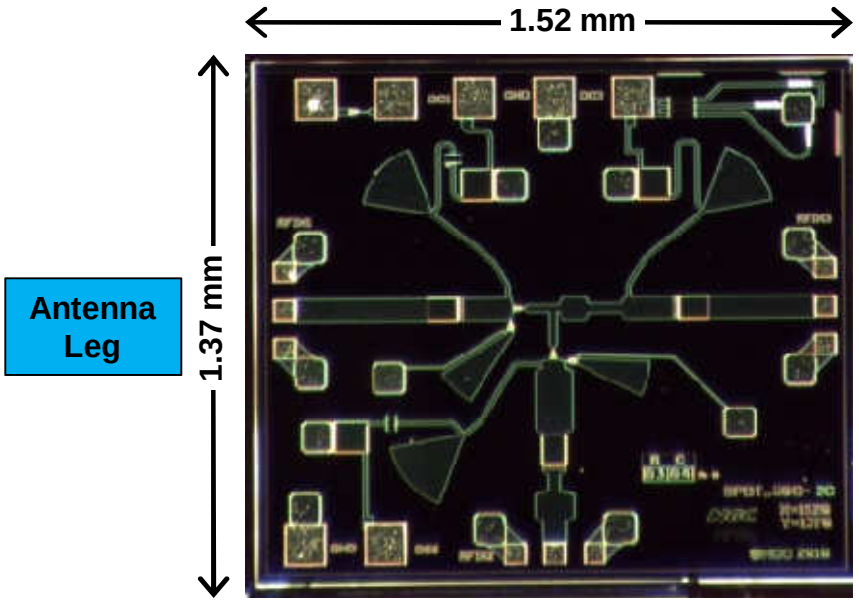


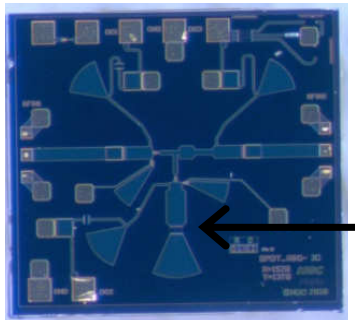


80-105 GHz MMIC Switch

Asymmetric Design

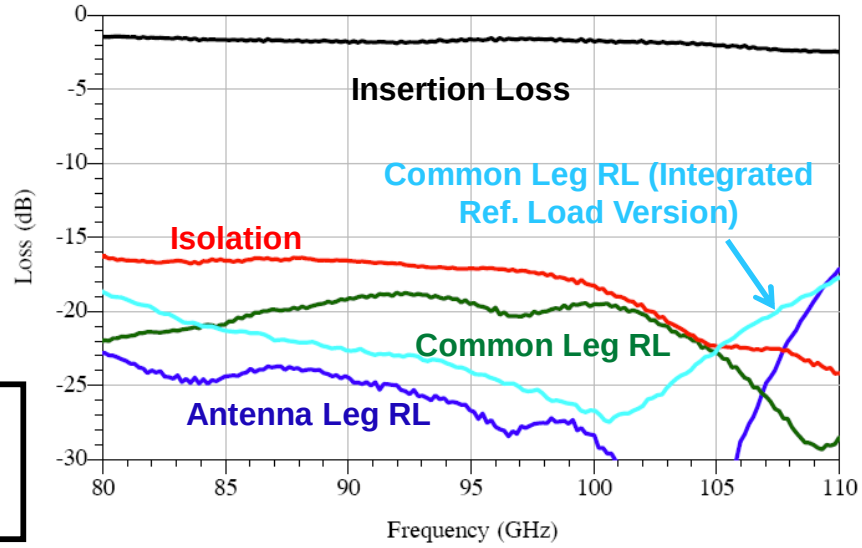
- Same technology as symmetric design (microstrip, SiN 2-layer MIM capacitors, etc.)
- Antenna and Common legs aligned and Reference leg at a 90°angle
- More practical implementation for radiometer receiver since “input” and “output” are aligned





Asymmetric design variation with integrated 50-Ω reference termination

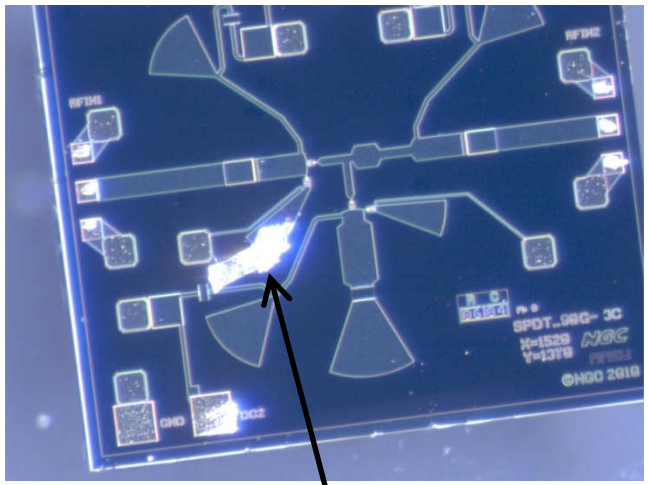
Measured Performance



80-105 GHz MMIC Switch

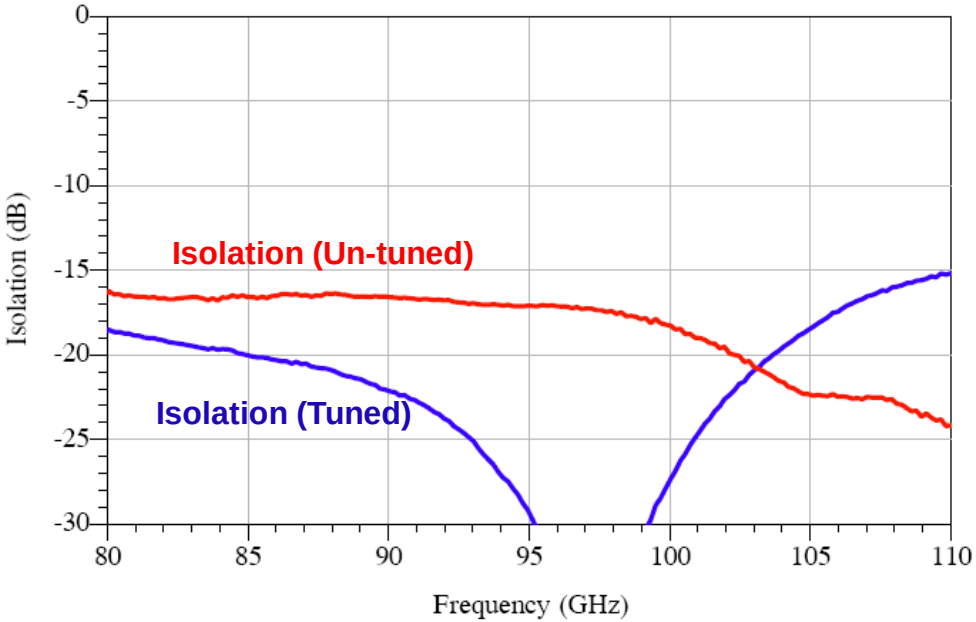
Post-Fabrication On-Chip Tuning of Isolation

- Higher frequency measurements demonstrated isolation was optimized for higher frequency
- By increasing effective electrical length of shunt diode radial stubs, optimal isolation was lowered to frequency range of interest



Tuning ribbon added to shunt diode radial stub

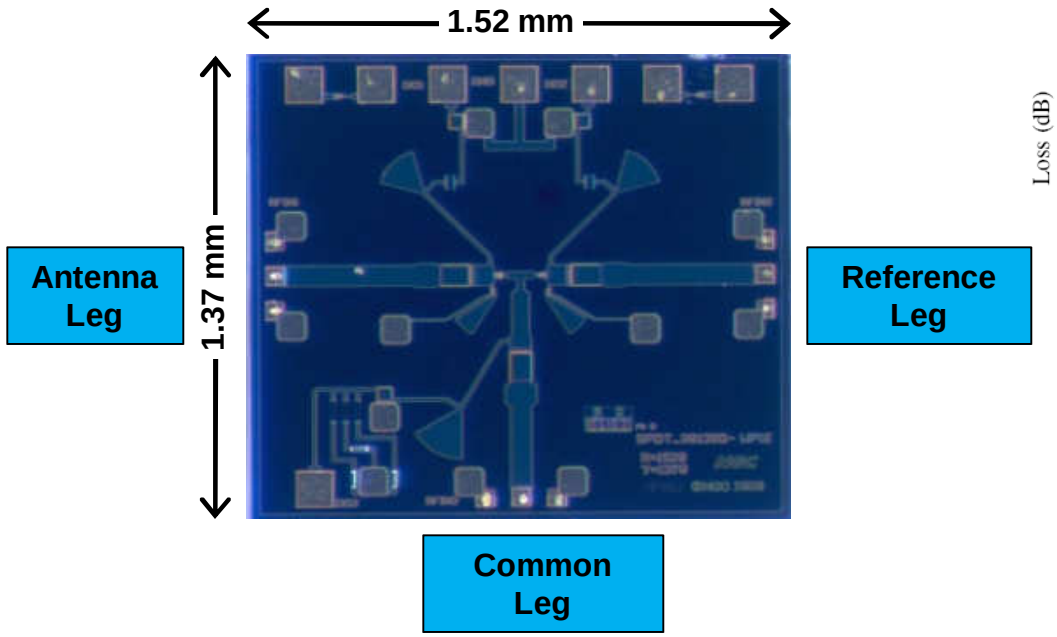
Measured Performance



90-135 GHz MMIC Switch

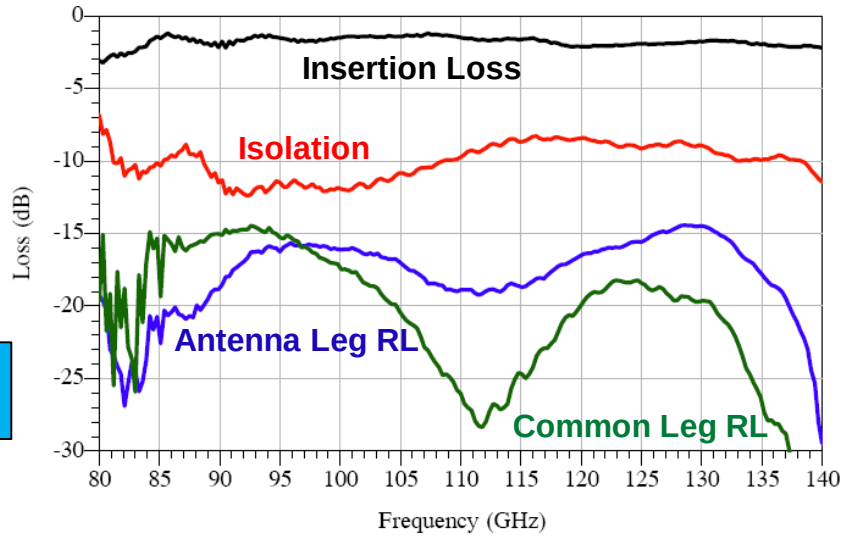
Symmetric Design

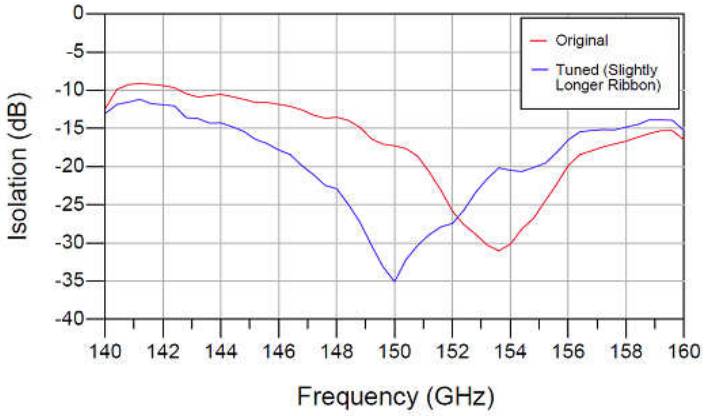
Same technology as 80-105 GHz design
(microstrip, SiN 2-layer MIM capacitors, etc.)



Preliminary tuning of shunt diode radial stub demonstrates decrease in isolation optimal frequency

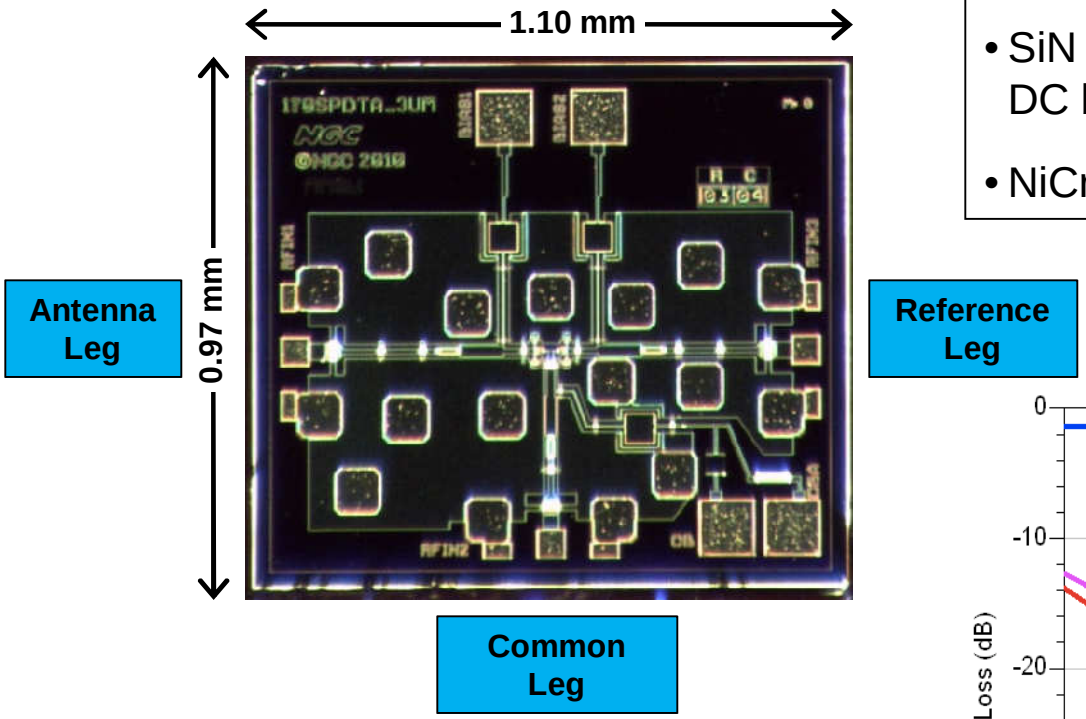
Measured Performance





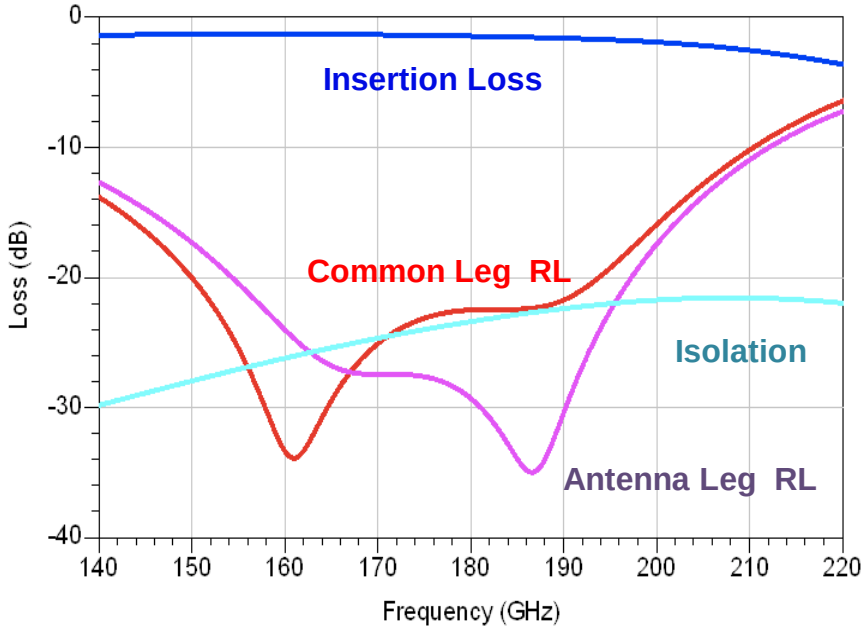
160-185 GHz MMIC Switch

Symmetric Design



- Coplanar waveguide design
- SiN 2-layer MIM capacitors for bypass and DC blocking capacitors
- NiCr thin-film process for resistors

Simulated Performance



Results

Switch	Insertion Loss	Return Loss	Isolation	Comments
80-105 GHz	<2 dB	>15 dB	>15 dB	
80-105 GHz (Asymmetric)	<2 dB	>18 dB	>15 dB	Isolation >20 dB from 85-103 GHz after on-chip tuning
90-135 GHz	<2 dB	>15 dB	>8 dB	
160-190 GHz	<2 dB	>20 dB	>20 dB	Simulated Results Only

Summary

- Dicke switched radiometers allow for correction of gain and noise figure fluctuations in components of receiver chain after the switch
- RF switches were designed to cover three frequency ranges, 80-105 GHz, 90-135 GHz, and 160-190 GHz
- Realized as monolithic microwave integrated circuits (MMIC) using microstrip and coplanar waveguide technology
- To date, 80-105 GHz and 90-135 GHz switches have been tested; 160-190 GHz switches have not yet been tested

Acknowledgements

- This work was supported by the NASA Earth Science Technology Advanced Component Technology ACT-08 Program led by Steven C. Reising of Colorado State University.
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